A Proposed Route to Thin Film Crystal Si Using Biaxially Textured Foreign Template Layers

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Motivation

- Silicon makes proven PV technologies
  Si is abundent, non-toxic, and capable of high efficiencies
- Crystal Si enables higher efficiencies BUT are expensive in $/area compared to amorphous thin films
- Thin-film c-Si would be best

Goal

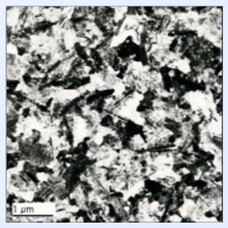
High quality 5-10 µm c-Si thin films on glass

Existing c-Si on glass technology

Grain boundaries limit carrier lifetimes

"Standard" route to c-Si on glass

1) Deposit amorphous Si
2) anneal at ~580°C



TEM

Small ~100nm grains
Random crystalline orientation

Previous approaches to reducing the impact of grain boundaries

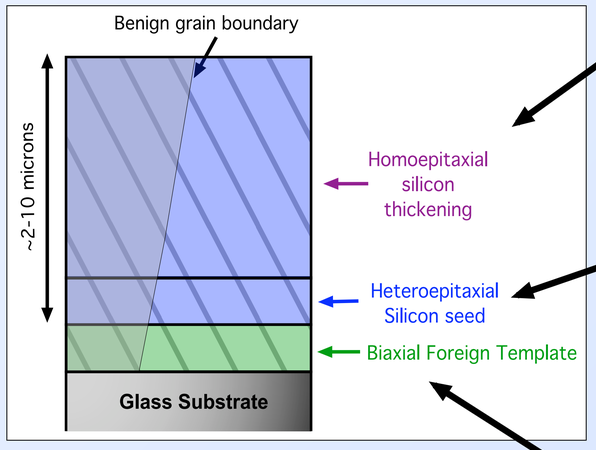
Passivate the boundaries with hydrogen

A. Turner et al., 10th EU PVSEC (Barcelona, 2005).

Increase the grain size

W. Fuhs et al., Sol. Energy (UK) 77 (6), 961-968 (2004).
A.G. Aberle et al., Prog. In PV. 13, 37-47 (2005).
C. E. Richardson et al., Symp. A (MRS Proc. **808**), 227(2004).

Our Approach: Control the orientation of the grains with a template layer



Homoepitaxial silicon thickening

Recent research has demonstrated low-T epitaxy

A. Straub et al., *J. Cryst. Growth* **268**, 41 (2004).
C.W. Teplin et al., *J. Cryst. Growth*, in press.

But growth on (100) c-Si is easiest

Solid phase epitaxy is also possible for thickening

Combines high-rate a-Si:H deposition with batch annealing

Heteroepitaxial Si/template interface

We anticipate that this will be the most challenging step at low-T

Silicon/γ-Al_2O_3 has been demonstrated at higher temperature

A. T. Findikoglu et al., *Adv. Mat.* **17**, 1527 (2005).

"Small-Angle" grain boundaries are less deleterious

If the grains in the silicon can be aligned, high mobilities are observed

W. Choi et al., "Dependence of carrier mobility on grain mosaic spread in <001> oriented Si films grown on polycrystalline substrates, submitted to Appl. Phys. Lett.

Biaxial textured oxides can be directly deposited on glass

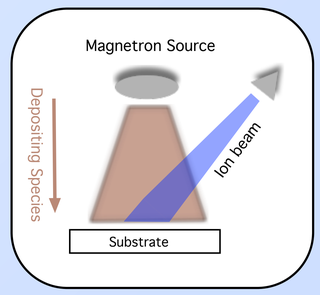
Biaxially-textured buffer layers are successfully applied to superconductors

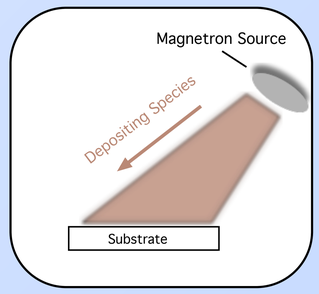
August 2004 MRS Bulletin is devoted to this topic

Biaxially textured template

Numerous materials have been deposited on glass with biaxial texture. We propose to use such a layer as a template for subsequent silicon epitaxy.

Ion-beam assisted deposition (IBAD) and inclined substrated deposition have been used to induce texture in films on disordered substrates.





Initial Experiments: CeO_2 templates

CeO_2 is lattice-matched to Si and has been deposited with biaxial texture on glass

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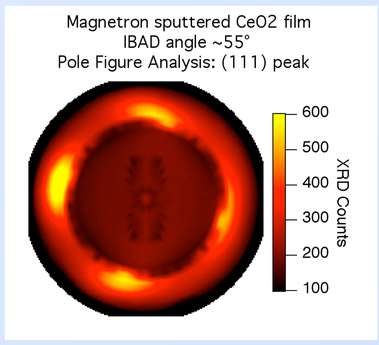
Glass/Template interface

Biaxially-textured CeO_2 obtained on glass by IBAD magnetron sputtering

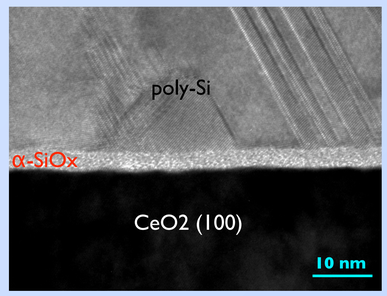


Template/CeO2 interface

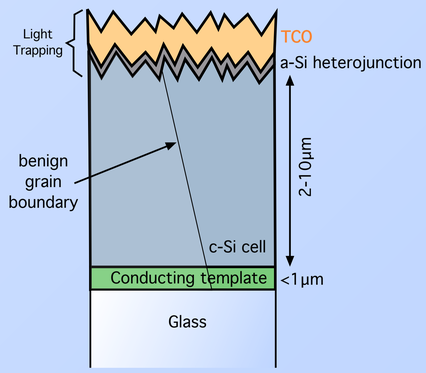
Tested using single-crystal CeO_2

α-Si deposited by HWCVD
Annealed at 580°C for 5 hours

SiO_x formation prevented epitaxy



Example Solar Cell Concept



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